Agriculture Association of Textile Chemical and Critical Reviews Journal (2023) 283-288

AATCC Review

12 November 2022: Received
18 March 2023: Revised
26 May 2023: Accepted
07 July 2023: Available Online

www.aatcc.peerjournals.net

Research Article Open Access

Production Efficiency and Agro-Economic Analysis of Sugarcane+ blackgram Intercropping System under Tropical Indian Conditions

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ABSTRACT

Intercropping in sugarcane allows more profitable land usage, and in Tamil Nadu, blackgram has been reported to be compatible with sugarcane. Participatory on-farm research trials comprising two treatments: sole sugarcane and sugarcane+blackgram intercropping (1:2) were conducted in the farmers' fields during 2019–20 and 2020–21 at Erode district of Tamil Nadu, India. The results of the experimentation on cane equivalent yield, production efficiency, economic efficiency, gross returns, net returns and benefit cost ratio were statistically analyzed using a randomized block design. To achieve spatial intensification, an additive design of intercropping was followed, wherein, the base crop's recommended plant population (sugarcane) was retained, and blackgram was introduced into the sugarcane inter-row spacing. Sugarcane+blackgram intercropping gave significantly more CEY (143.20 and 134.73 t ha-1) than sugarcane alone (127.58 and 122.30 t ha-1). Further, its production efficiency (392.37 and 369.13 kg cane day-1) was 12.24% and 10.17% higher than sole sugarcane cropping during 2019-20 and 2020-21, respectively. The gross (Rs. 375191 and 353001 ha-1) and net returns (Rs. 174944 and 146674 ha-1), and B: C ratios (1.88 and 1.71) were significantly higher with sugarcane+blackgram intercropping than that of sole cropping. Besides, intercropping also recorded (Rs. 479.30 and 401.85 ha-1day-1) 30.54% and 22.04% higher economic efficiency than mono sugarcane cropping in both the years of experimentation. Thus, sugarcane+blackgram intercropping was found and economically viable than sole sugarcane.

Keywords: *Economic efficiency, Intercropping, Production efficiency, Sugarcane*

INTRODUCTION

Sugarcane is an important cash crop in India both sociologically and economically [1, 2, 3]. Pulses like chickpea, pigeonpea, lentil, fieldpeas and blackgram are grown in India, due to a lack of arable land, it is impossible to intensify crop production through conventional vertical and horizontal expansions. Inclusion of short-duration pulses in intercropping systems, can help to increase area under pulses, as intercropping allows for optimal utilization of growth resources in both the spatial and temporal dimensions [4, 5] in a given place. Intercropping optimizes natural resources use and stabilizes crop yield [6, 7] thus can address global food security and poverty alleviation in developing countries [8,9]. Sugarcane is no exception, and it could provide enough opportunities for intercropping pulses [10, 11] and more net returns [12]. Indian scenario depicts a grim picture of stagnant sugarcane productivity [13] and high cultivation costs, necessitating timely crop diversification to make sugarcane cultivation more remunerative and lucrative. Intercropping sugarcane+sunnhemp, in combination with crop residue recycling reduces soil compaction, enhances soil physical conditions, intensifies soil microbial activity and restores organic matter in the plant-ratoon-ratoon crop cycle [14]. Crop residue recycling of pulses and legumes addresses the issue of decreasing soil organic carbon [15]. Sugarcane + soybean intercropping enhanced soil nitrogenase enzymatic activity by 57.4% in comparison to sugarcane alone, which contributed to increase in dry biomass weight and yield of 35.44 and 30.57%, respectively [16]. The organic matter content of sugarcane soil increased due to companion cropping of pulses [17], whereas cowpea and green gram has a significant carry over effect [18]. Pulse crop residue recycling offers an effective solution to the critical issue of soil organic carbon depletion, which is mostly caused by indiscriminate/imbalanced fertilizer usage and a lack of use/availability of organic manures [19]. The sugarcane rhizosphere occupies less than one-third of the soil during early growth period. In the interspaces, weed grows and affect the sugarcane tillering and growth [20]. During formative phase of sugarcane, the mean light interception is less than 30% [21] and up to the 70 % of the land between cane rows is left unutilized. However, pulses like cowpea, sunnhemp, and soybean with a good canopy cover as smother crops in sugarcane-based intercropping suppressed weeds by 36.3%, 32.3%, and 32.0%, respectively, and proved to be as effective as hand weeding [22]. In sugarcane-based intercropping at ICAR-SBI, Coimbatore, found that amaranthus (65.26%), sunnhemp

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DOI: https://doi.org/10.58321/AATCCReview.2023.11.03.283

(47.97%) and sesame (28.90%) intercepted more light than a sole sugarcane crop [23]. Sugarcane+pulses intercropping resulted in improved crop yield and increased land use efficiency, especially under adverse climatic conditions [24, 25, 26]. In temporal and spatial complementarities in sugarcane-based intercropping, found significantly higher germination and tiller count in sugarcane+blackgram intercropping than sole sugarcane. Sugarcane+ sunnhemp intercropping recorded higher cane yield (173 t ha-1) than sugarcane alone [27]. Sugarcane+blackgram intercropping efficiently increased total yield, monetary return, resource use, and fulfilled farmers' diverse needs. Black gram could be raised as profitable intercrops [28] in Tropical Indian condition. Participatory on-farm research experiments on sugarcane+blackgram intercropping were conducted with the goal of improving productivity, profitability, and food security in tropical conditions.

Materials and Methods

Experimental site

Under the National Food Security Mission (NFSM) project, trials were taken up for two years during –20 and 2020–21 in farmer's fields in a participatory mode in the Aval Poonndurai (Latitude: 11°14'2"N, Longitude: 77°43'3"E and 220 MSL) and other nearby villages. These ten villages, viz., Vellode, Aval Poondurai, Erode, Modakuruchi, Ganapathypalayam, Chennimalai, Rajapalayam, Perumapalayam, Poondurai Semur and Thottipalayam were from Erode district of Tamil Nadu. Registered growers of Sakthi Sugars Ltd., Poonthurai semur participated in the trials. These villages come under the Eastern Ghats and Tamil Nadu Uplands as per Agro-Ecological Region/Sub Region (ICAR-Classification) and receive annual rainfall of between 575 to 833 mm. On-farm research trials (Table 1) with two treatments, i.e., T1: sole sugarcane and T2: sugarcane+blackgram intercropping (1:2) were conducted with an area of 1.0 ha each.

Sugarcane and blackgram were planted at 150 and 30 cm of row spacing, respectively. Blackgram variety Vamban (VBN-Bg} 6, developed at the National Pulses Research Centre (TNAU), was provided to farmers as a critical input. A "TNAU pulse wonder" a micronutrient mixture foliar spray at peak flowering of blackgram was done @ 5 kg /ha to boost pulse yield, decrease flower shedding, and increase drought tolerance. For management of weeds, post emergence application of pendimethalin @ 0.75 kg a.i./ha was followed in sugarcane+blackgram intercropping system. Recommended irrigation management and plant protection measures were followed.

2. Agro-economic advantage analysis

Crop equivalent yield was used to make economic return comparisons. The economic yield of blackgram was converted to equivalent yields of sugarcane and the comparison was made on the basis of sugarcane equivalent yields. The cane equivalent yield of the sugarcane+blackgram intercropping system was calculated using the following equation:

$$\text{CEY} = \sum_{i=1}^{n}(Y_i e_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
n = 1, 2, 3....... n, total number of crops in association
Yi = the economic yield of ith crop, and
ei = the cane equivalent factor of the ith crop
ei was calculated using the formula

$$e_i = \frac{P_i}{P_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,
Pi = the price of unit weight of the ith crop, and
Ps = the price of the unit weight of cane

Evaluation of production efficiency of the system

Production efficiency

The total output per unit area per day of the sugarcane+blackgram intercropping system is referred to as production efficiency. Under the sugarcane+ blackgram intercropping system, output is determined by the total amount of production as well as the length of the total period of cultivation. While calculating system productivity, cane equivalent yield (CEY) was divided by the duration of the sugarcane+blackgram intercropping system.

$$\text{Production efficiency(kg/ha/day)} = \frac{\text{Cane equivalent yield(kg/ha)}}{\text{Total duration of cropping(days)}} \ldots (3)$$

Relative Production Efficiency: It is the comparative advantages obtained through sugarcane+blackgram intercropping over sugarcane alone, expressed in percentage

$$\text{Realtive Production efficiency(\%)}$$

$$= \frac{\text{CEY(S+B Intercropping)} - \text{CaneYield(Sole Cane)}}{\text{CaneYield(Sole Cane)}} \times 100 \ldots\ldots (4)$$

Economic efficiency

The economic efficiency of sugarcane+blackgram intercropping and sugarcane sole cropping systems was calculated to determine per day return. Basically it is the ratio of net returns (NR) to cropping days used in the sugarcane+blackgram intercropping system. This metric also known as income per day quantifies the efficiency of the intercropping system in terms of monetary value..

$$\text{Economic efficiency(Rs/ha/day)}$$

$$= \frac{\text{Net returns(Rs)}}{\text{Total duration of cropping(days)}} \ldots\ldots\ldots\ldots (5)$$

Relative Economic Efficiency

It is the comparative advantages obtained through sugarcane+blackgram intercropping over the sole sugarcane expressed in percentage.

$$\text{Relative Economic efficiency(\%)} =$$

$$= \frac{\text{NR in netercropping} - \text{NR in sole sugarcane}}{\text{NR in sole sugarcane}} \times 10 \ldots\ldots (6)$$

Economic Assessment of sugarcane+blackgram intercropping system

The cost of cultivation was computed by summing the expenses of inputs and labour for sugarcane and blackgram crops from planting to harvest, including field preparation. The total monetary returns of the economic products gained from sugarcane and blackgram were used to calculate gross returns. The gross returns of the sugarcane and blackgram intercropping were calculated per hectare as per the following equation.

$$\text{Gross Return(Rs)} = \sum_{i=1}^{n} \begin{matrix}\text{Returns from cane yield} \\ +\text{returns from Grain yield}\end{matrix} \ldots (7)$$

To compare the systems true profitability, net returns of the sugarcane+blackgram intercropping system were computed by subtracting cultivation costs from gross returns.

$$\text{Net Return(Rs)} = \sum_{i=1}^{n} \left(\begin{matrix} \text{Gross return} - \\ \text{Total cost of production} \end{matrix} \right) \ldots\ldots (8)$$

The benefit: cost index calculates the profit and costs associated with sugarcane sole cropping and sugarcane+blackgram intercropping systems. The benefit-to-cost ratio was calculated using the returns and cultivation costs as given in the equation.

$$\text{Benefit Cost Ratio} = \sum_{i=1}^{n} \left(\begin{matrix} \text{Gross return/} \\ \text{Total cost of production} \end{matrix} \right) \ldots (9)$$

3. Statistical analysis

The results of the experimentation on cane equivalent yield, production efficiency, economic efficiency, gross returns, net returns and benefit cost ratio were statistically analyzed using a randomized block design[29]. Fischer's method of analysis of variance was used to analyze the data and the level of significance employed in the F and t tests was P = 0.05. When the F test was found to be significant, the critical difference values were calculated at a 5% probability level.

RESULTS AND DISCUSSIONS

Sugarcane+blackgram System productivity, Production efficiency and Relative Production efficiency

The results presented in Table 1, showed that spatial intensification of sugarcane grown with wide row spacing (150 cm) is very much plausible by using blackgram as an intercrop with better complementarities without affecting sugarcane cane yield. This could be explained by the temporal niche differentiation (TND) effect of sugarcane+blackgram intercropping wherein by consuming different nutrients or using different areas of the environment, both species differentiate their niches, compete less strongly and are thus more likely to coexist for 70 days in the system. Blackgram can be harvested prior to the sugarcane tillering phase, providing an improved soil environment with the added benefit of nitrogen fixation, as well as an additional cane yield and interim income to sugarcane growers. The sugarcane+blackgram intercropping produced significantly higher CEY of 143.20 and 134.73 t ha-1 respectively, during 2019–20 and 2020–21 than sole sugarcane (127.58 and 122.30 t ha-1). The improvement in yield due sugarcane +Blackgram intercropping over sole sugarcane was to the tune of 12.24 and 10.16 per cent, respectively during 2019–20 and 2020–21. The results of the present study corroborated the findings of[30] who reported significantly higher cane yield in sugarcane+blackgram (146.56 t ha-1) than sugarcane+ greengram (144.67 t ha-1), sugarcane+soybean intercropping (119.57 t ha-1) and sole sugarcane (138.65 t ha-1). Earlier work has demonstrated that sugarcane based intercropping improved both yield and nutrient uptake over sole sugarcane. When legumes precede cereals, the yield of the succeeding crop is generally higher. Depending on how legumes are grown, different amounts of nitrogen may be left for the succeeding crop to utilize. Nitrogen carryover for succeeding cereals in blackgram can be as high as 55 kg [31, 32]. The sugarcane+legume intercropping system were proven to be more effective in nitrogen fixation than monoculture. The intercropping system helped to maintain the natural pH of the soil while also increasing organic matter levels. Intercropping improves soil microbial activity [33] and diazotrophic population, resulting in increased dehydrogenase, urease, protease, and nitrate reductase activities in intercropped soil compared to monoculture. Nitrate reductase is the primary enzyme involved in denitrification, which contributes to nitrite reduction in the atmosphere and so helps to reduce harmful nitrite. Soil proteases, on the other hand, are important for N mineralization, which is required for plant development and nutrient availability [34]. During 2019–20 and 2020–21, the sugarcane+blackgram intercropping system had the highest production efficiency of 392.37 and 369.13 kg cane day-1, besides more productive (12.24 and 10.17 % RPE) nature than sole sugarcane. Intercropping sugarcane and blackgram proved to be more advantageous, as it resulted in higher crop yields per unit land area, per day.

Sugarcane+blackgram System profitability, Economic Efficiency and Relative Economic Efficiency

Table 2 shows the results of Agro-economic advantage analysis in terms of gross returns, net returns, B:C ratio, economic efficiency and relative economic efficiency for sugarcane+blackgram and sole sugarcane cropping. The economic benefits of sugarcane+blackgram cropping systems i.e. gross returns (375191 and 353001 Rs ha-1), net returns (174944 and 146674 Rs ha-1), and B: C ratios (1.88 and 1.71) were found to be significantly superior over sole sugarcane cropping systems. Higher profitability of sugarcane+blackgram under tropical Indian conditions was also observed [30]. Intercropping using a variety of intercrops has led to substantial improvements, with returns ranging from 12% to 34%. Similarly under Indian subtropical conditions [35] also observed the highest cane equivalent yield (112.85 t ha-1) and B: C ratio (2.16) in the sugarcane+French bean intercropping system indicating that sugarcane+pulses intercropping systems are economically more viable than sole sugarcane (cane equivalent yield 76.33 t ha-1 and B/C ratio of 1.49).

Perusal of data on economic efficiency and relative economic efficiency given in Table 2 revealed that sugarcane+blackgram intercropping system recorded the higher economic efficiency (479.30 and 401.85 Rs ha-1day-1) than sole sugarcane. The overall economic efficiency improvement of the sugarcane+blackgram intercropping system over solitary sugarcane planting ranged from 30.54% to 22.04%.

CONCLUSION

The sugarcane+blackgram (1:2) intercropping system produced considerably greater cane equivalent yield and maximized production as well as economic efficiency of sugarcane farming over sole sugarcane planting. As a result, intercropping sugarcane with blackgram could be a viable choice for economic food security of small and marginal sugarcane farmers in tropical Indian conditions.

Table 1: Varieties used, spatial arrangement and fertilizer application for on farm research trials

Particulars	Sole Sugarcane	Sugarcane+Blackgram Intercropping
Variety	Co 86032	Co 86032 and Black gram : Vamban 6
Row proportion of sugarcane and blackgram	Sole sugarcane planted in ridges and furrow with row to row spacing of 150 cm	In additive series, without changing the plant population of base crop sugarcane, blackgram is introduced by keeping the row proportion of 1:2.
Spatial arrangement	150 cm for sole sugarcane	Blackgram with the crop geometry of (30×60 cm) was sown as intercrop in two sugarcane row spaced at 150 cm
Planting time	June 2019 and June 2020	June 2019 and June 2020 and blackgram was sown 10 days after planting of sugarcane
Herbicides used for weed management	Pre-emergence spraying of Atrazine	Post-emergence spraying of Pendimethalin
Fertilizers	Recommended dose of fertilizer (100% RDF) to sugarcane	100 % RDF for sugarcane and 50 % of 25:50:25 Kg NPK/ha and "*Pulse wonder*" a crop booster @ 5 kg /ha was applied to blackgram crop.

*RDF: Recommended Dose of Fertilizer;

Table 2: Equivalent yield Economic returns of sugarcane +blackgram intercropping system (2019–20 and 2020–21)

Crop seasons/treatments	Cane equivalent yield (t ha^{-1})	Gross return (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
2019-20				
Sole sugarcane	127.58	334260.10	134013.1	1.68
Sugarcane+Blackgram	143.20	375191.10	174944.1	1.88
SEm ±	5.65	14802.95	12379.91	0.07
CD(p=0.05)	11.60	303773.0	25402.10	0.15
2020-21				
Sole sugarcane	122.30	320424.21	120177.21	1.60
Sugarcane+Blackgram	134.73	353000.87	146673.87	1.71
SEm±	2.94	9010.32	11081.38	0.06
CD(p=0.05)	6.12	18738.03	23045	0.10

Table 3: Production and Economic efficiency of the sugarcane +blackgram intercropping system for crop seasons 2019–20 and 2020–21

Crop seasons/treatments	Production efficiency (kg $ha^{-1}day^{-1}$)	Relative Production Efficiency (%)	Economic efficiency (kg $ha^{-1}day^{-1}$)	Relative Economic Efficiency (%)
2019-20				
Sole sugarcane	349.53	0	367.16	0
Sugarcane+Blackgram	392.37	12.24	479.30	30.54
SEm ±	15.51		40.58	
CD(P=0.05)	31.83		83.27	
2020-21				
Sole sugarcane	335.06	0	329.25	0
Sugarcane+Blackgram	369.13	10.17	401.85	22.04
SEm ±	8.17		28.68	
CD(P=0.05)	17.00		26.02	

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